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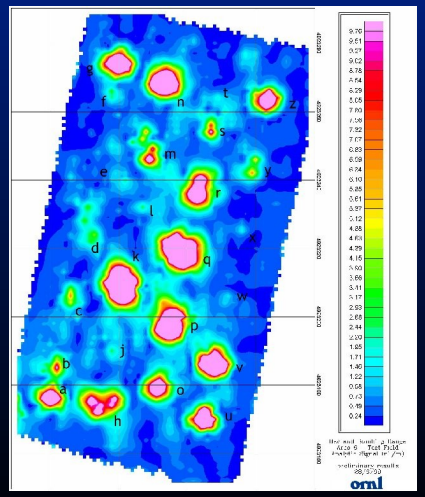
Utilization of Airborne Magnetometry for the Detection, Characterization and Identification of Unexploded Ordnance and HTRW Pits and Trenches

CAUTION
FORMER
BOMBING RANGE
The Area Beyond This Sign Was Used For Military
Purposes in Past Years
For Your Safety, Do Not Disturb Unknown Objects
They Could Accidentally Explode
Report Any Suspicious Objects to
Badlands Bombing Range Project Office-867-1271
or
Badlands National Park Office-433-5231



"Environmental Stewardship"

Scott Millhous

18 April 2001

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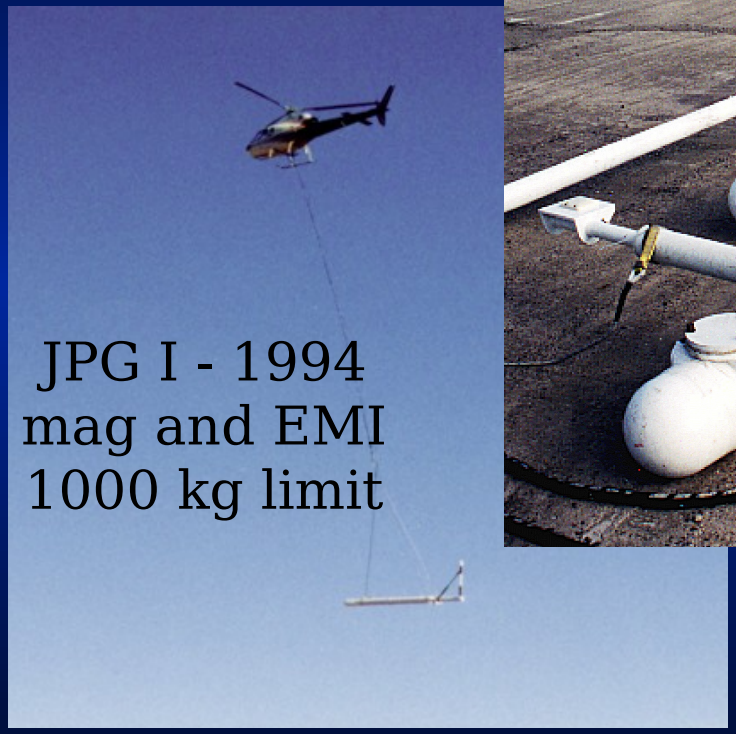
Evolution of the technology



JPG I - 1994
mag and EMI
1000 kg limit

Juterbog - 1996
triaxial mag
gradiometer
100 kg limit

Edwards AFB- 1997
3 boom mag array
20 kg limit

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1999 Badlands Demo Commercial HM-3 System

- Lower altitudes
- Higher sample rates
- Refined Processing
- 6-8# limit

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1999 Badlands Test Grid

- Sized at 100 m by 50 m with 20 m separation of items N-S and 15 m E-W.
- 25 seeds 6-65# ; 0.3’ - 4.4’ deep
- Location in an clean open area with little geological background. Open approach and departure for over-flight.

Item 6001 – 2" galvanized pipe

Item 6002 – rebar/rod section

Item 6003 – 2" galvanized elbow

Item 6004 – steel channel

Item 6005 – 2" galvanized pipe

Item 6006 – 2" galvanized pipe with flange

Item 6014 – 100lb. bomb fragments

Item 6015 – 250lb. bomb simulant

Item 6016 – 250lb. bomb simulant

Item 6017 – 100lb. bomb

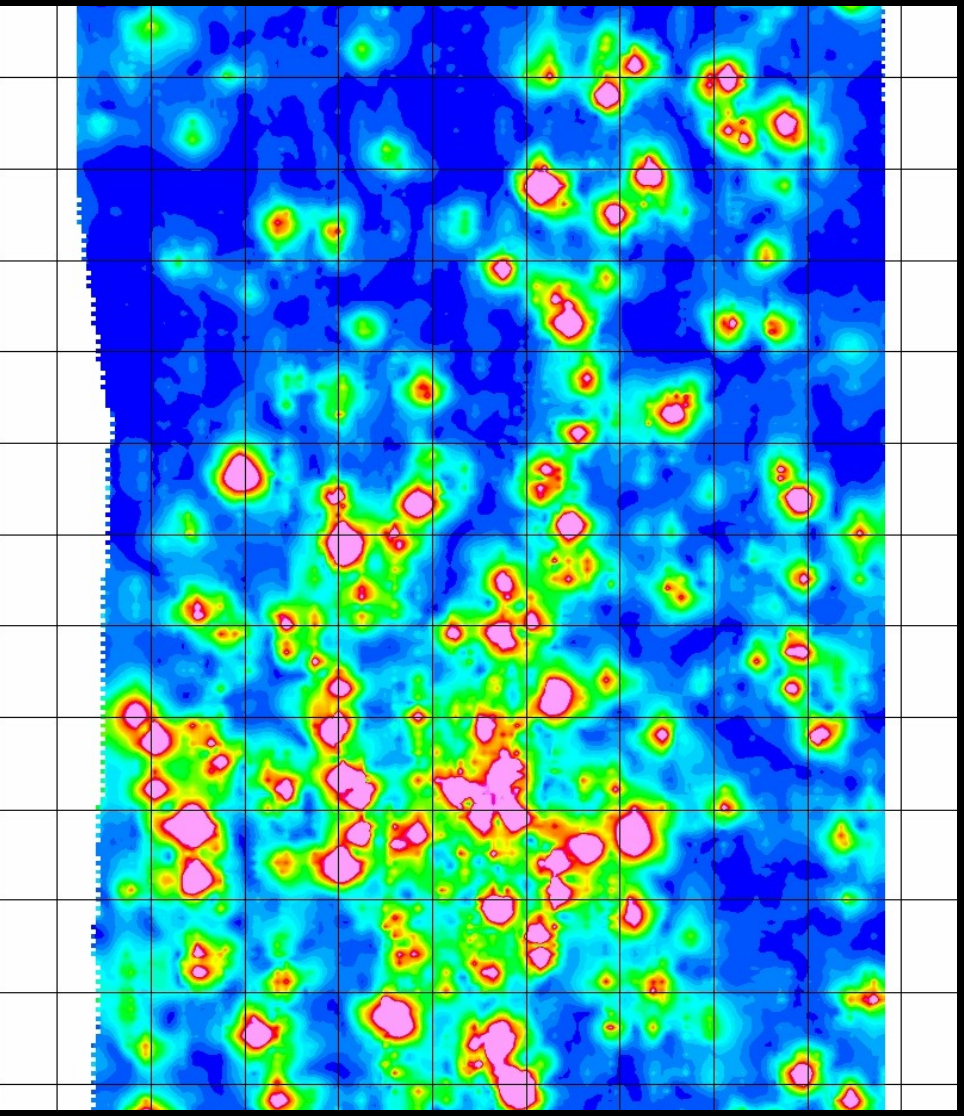
Item 6018 – 100lb. bomb fragment

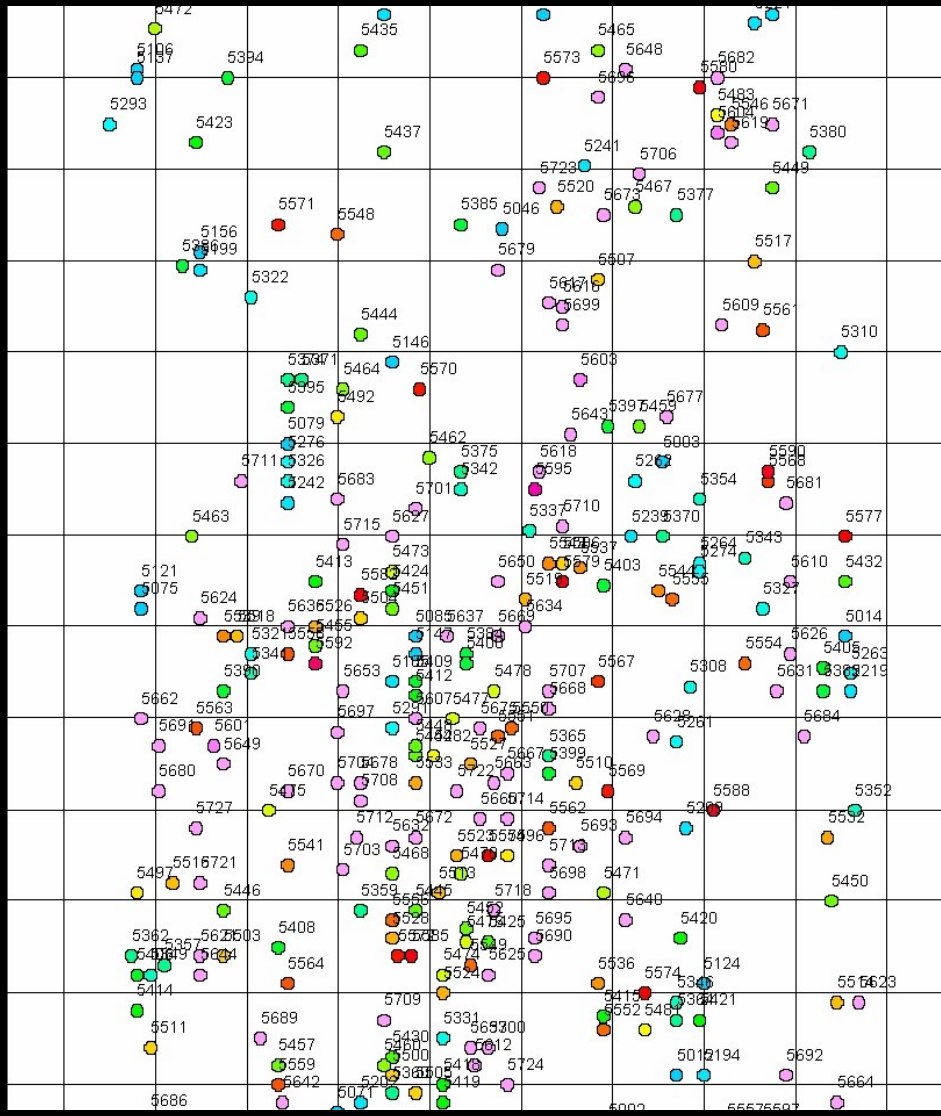
Item 6019 – 2.75" rocket

Table 1. – Test Grid Ordnance, Simulates, and Miscellaneous Items. ID6000 series by ORNL 1999,

Item	Description	Weight (in lbs)	Length (in ft)	Width or Diameter (in ft)	Azimuth	Depth to Top of Item (in ft)
6001	2" Galvanized pipe w/end cap	6	1.1	0.2	East-West	1.6
6002	3 ea. Rebar/rod sections	12	2.5	-	Random	1.85
6003	2" Galvanized pipe elbow	10	2.0	0.2	-	2.3
6004	Steel channel	15	1.75	0.25 x 0.25	-	2.1
6005	2" Galvanized pipe w/end cap	6	1.1	0.2	East-West	1.0
6006	2" Galvanized pipe with two cast floor flanges	10	1.2	0.2	East-West	1.3
6007	Empty	-	-	-	-	-
6008	I-beam section	29	1.2	0.35	East-West	1.4
6009	Cast cylinder	25	0.85	0.4	-	1
6010	4 ea. Rebar/rod sections	9	2.5	-	Random	1.5
6011	I-beam section	10	0.3	0.67	-	2.1
6012	Rod	9	1.7	0.12	North-South	1.6
6013	100-lb. Bomb fragments	unknown	-	-	-	0.3-0.5
6014	100-lb. Bomb fragments	19	-	-	-	1.0-1.6
6015	250-lb. Bomb Simulant	50	5.3	1.2	North-South	4.4
6016	250-lb. Bomb Simulant	65	5.3	1.2	East-West	2.4
6017	100-lb. Bomb (intact)	50	4.0	0.65	North-South	3.1
6018	100-lb. Bomb fragments	32	2.2	0.8	North-South	1.3
6019	2.75" Rocket (nose section)	9	0.9	0.25	East-West	1.5
6020	100-lb. Bomb fragments	unknown	-	-	-	0.3-0.5
6021	100-lb. Bomb fragments	unknown	-	-	-	0.3-0.5
6022	2.75" Rocket (cylinder)	9	0.75	0.25	East-West	2
6023	Steel T-Section Channel	9	1.05	0.25	-	2.4
6024	Cast Square Plate	55	1.1	1.4	-	3
6025	2 ea. 2.75" Rocket Simulants	12	0.75	0.25	North-South East-West	1.3

Badlands Bombing Range
Site 5, Quadrant 2 - Target Pick List





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Ground Truth

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Ground Truth

Burial Pit @ NW Corner of Area 4 - 1-4’ Depth

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Field Results

- More than 2,000 total anomalies identified and cataloged
- 82 anomalies excavated; 67 M-38's, 7-2.25-inch rockets,
- Dozens of M-38's uncovered in disposal pit

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2000 Prototype System ORAGS-HA* System

* Oak Ridge Airborne Geophysical System – Hammerhead

- 8 magnetometers
- 1.75m spacing
- Up to 1200 samples/sec
- Novatel real-time DGPS positioning
- PicoDas navigation
- Laser altimeter
- 5-7# limit

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2000 BBR Test Site

- Tripled in size from 1999 test site (range from 50m X 100m to 100m X 150m)
- Included ordnance that frequently occurs

  at other sites, though not at BBR:
  - 105 and 155mm artillery shells
  - 20mm rounds, mortars, and rockets
- Depths from 0 to 4.4 ft

Badlands Test Site

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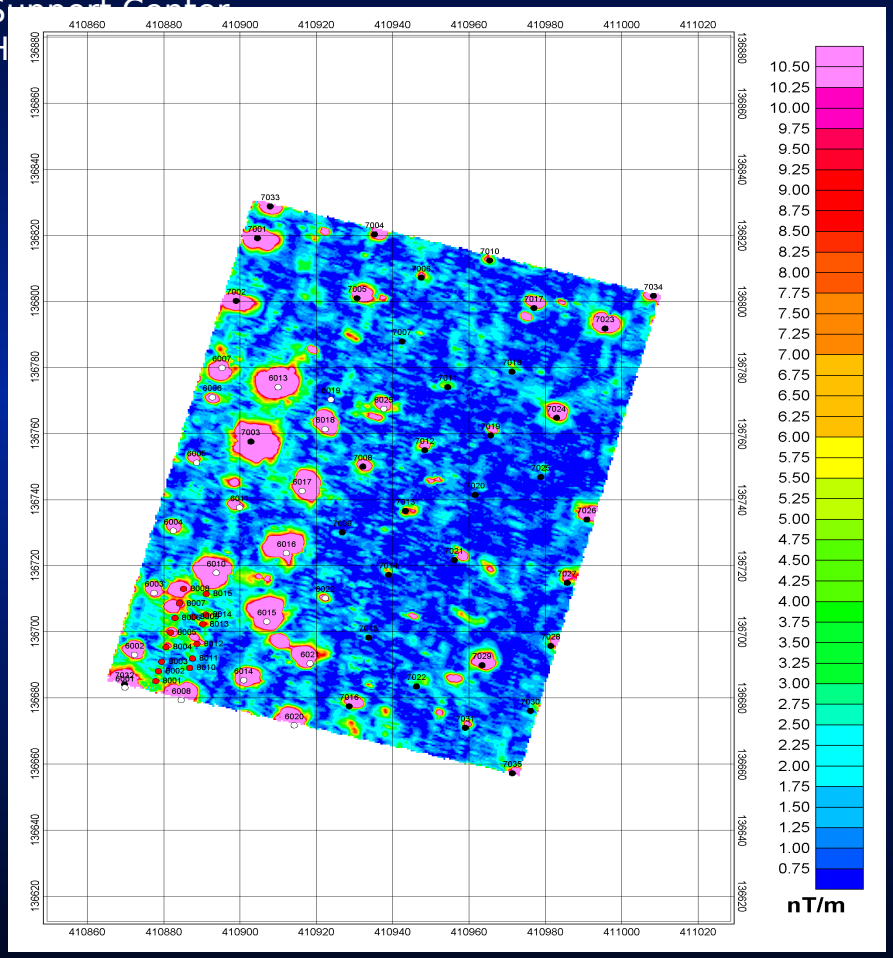
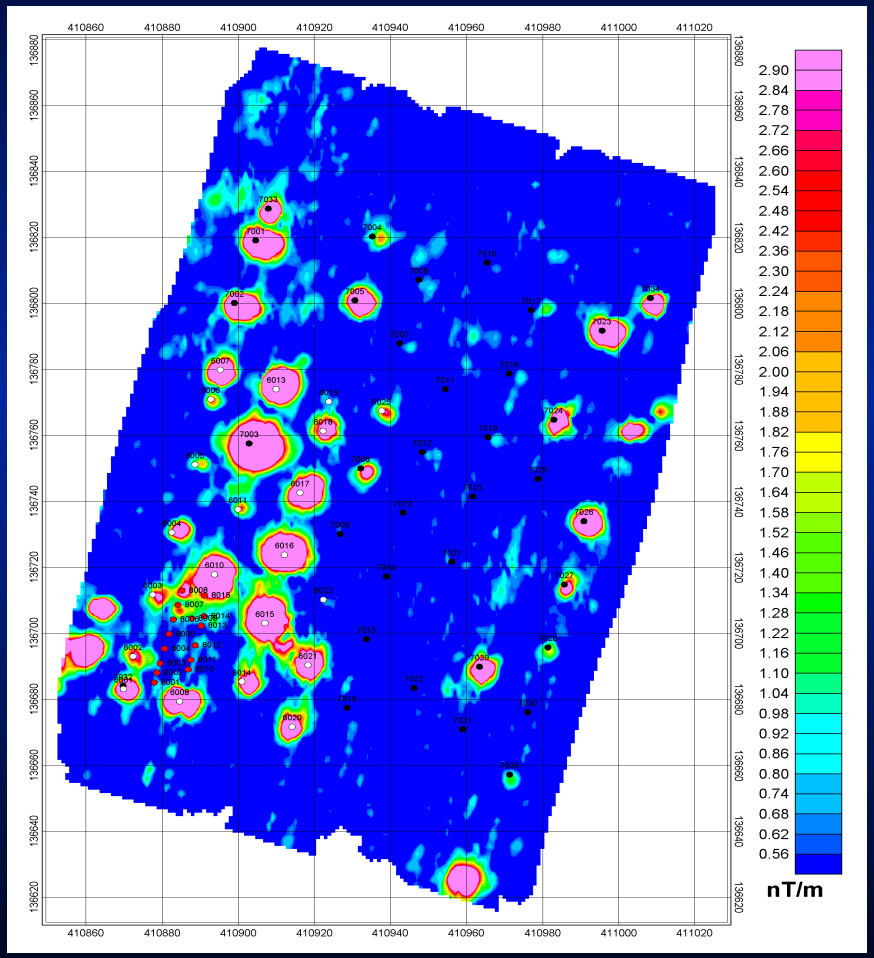


Ground-based G-858



ORAGS-HA Airborne system

BBR Test Site Results

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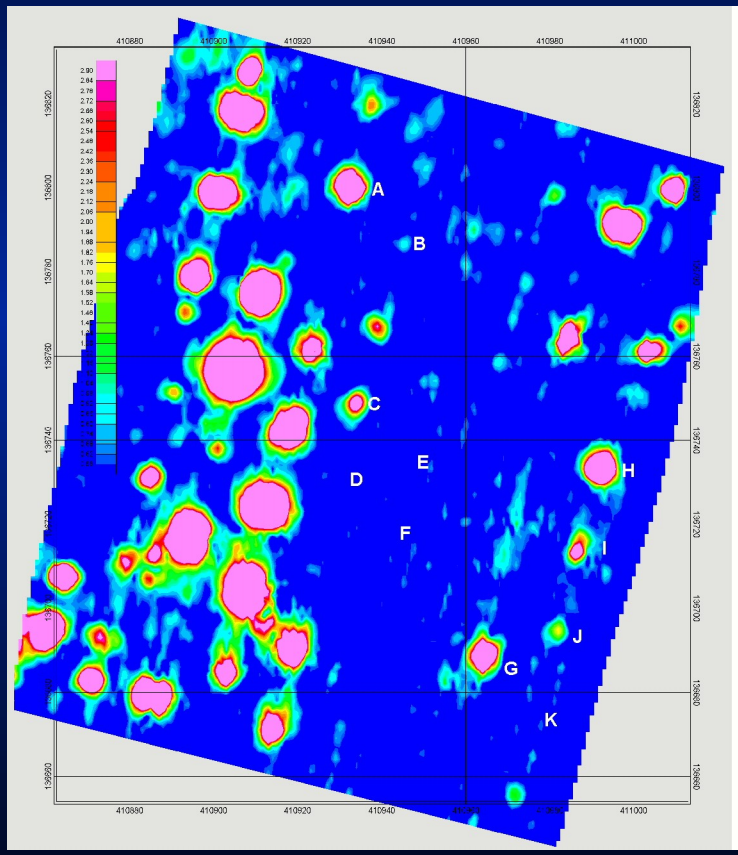

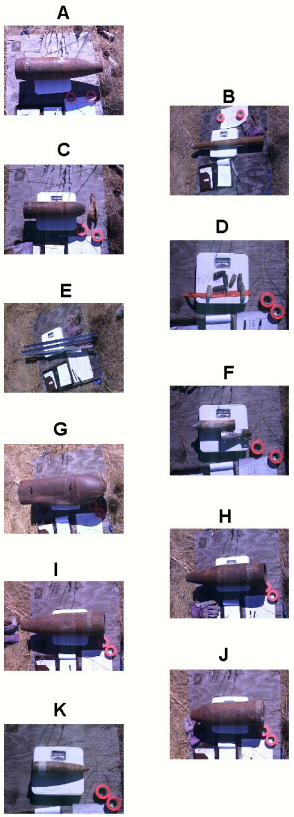

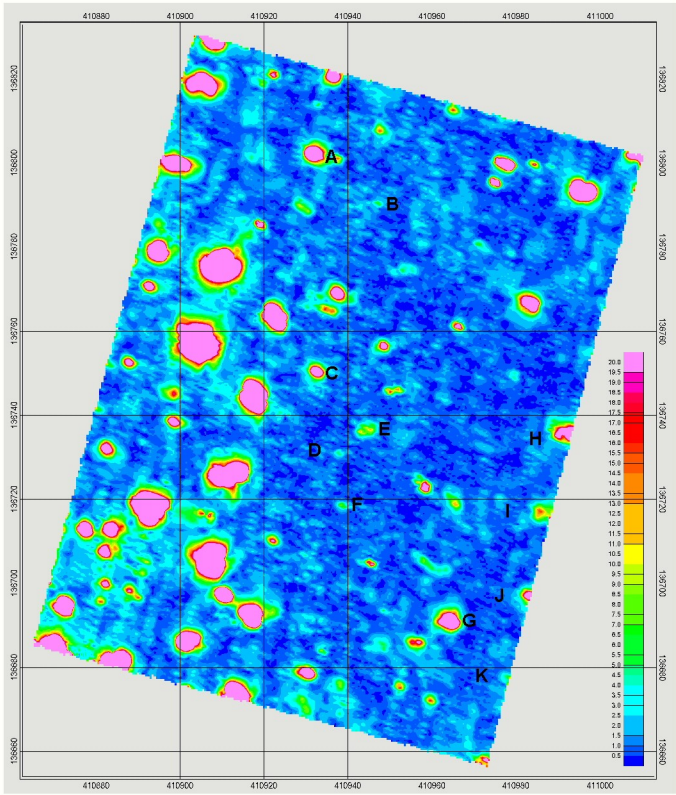

Airborne

Ground

Table 1. – Test Grid Ordnance, Simulates, and Miscellaneous Items. ID7000 series by ORNL 2000,

Item	Description	Weight (in lbs)	Length (in ft)	Width or Diameter (in ft)	Azimuth	Depth to Top of Item (in ft)
7001	Galvanized stove pipe	4	2.50	0.58	East-West	3.17
7002	Box beam	10	2.17	0.41x0.17	East-West	2.00
7003	250#bomb	115	2.13	0.79	Vertical	3.25
7004	105mm round	19	1.25	0.33	Vertical	2.17
7005	155mm round	53	1.96	0.50	Vertical	2.25
7006	105mm round	18	1.25	0.33	North-South	2.42
7007	61mm mortar	2	0.71	0.21	Vertical	1.17
7008	105mm round	19	1.25	0.33	Vertical	2.58
7009	2.75" rocket	5	2.17	0.23	North-South	2.00
7010	105mm round	18	1.25	0.33	East-West	2.42
7011	81mm mortar	8	1.42	0.27	North-South	2.58
7012	81mm mortar	8	1.42	0.27	North-South	1.08
7013	Aluminum rod	1	3.00	0.08	East-West	2.67
7014	Aluminum rod	1	3.00	0.08	East-West	1.58
7015	Aluminum rod	1	3.00	0.08	East-West	1.00
7016	81mm mortar	9	1.42	0.27	Vertical	1.42
7017	Coiled wire	1	0.00	1.33 loop	Horizontal	0.00
7018	60mm illumination round	2	1.27	0.21	Vertical	0.25
7019	60mm illumination round	4	1.27	0.21	North-South	0.42
7020	60mm illumination round	4	1.27	0.21	East-West	0.42
7021	20mm rounds (x24)	2	0.27	0.04	Scattered	0.00
7022	81mm mortar	7	1.42	0.27	North-South	1.83
7023	Steel pipe	9	1.58	0.25	East-West	2.00
7024	2.25" rocket	10	2.40	0.19	North-South	1.75
7025	60mm mortar	3	0.63	0.25	Vertical	1.33
7026	155mm round	56	2.00	0.50	Vertical	1.83
7027	155mm round	56	1.96	0.50	North-South	2.42
7028	155mm round	56	1.67	0.50	East-West	2.83
7029	100#bomb	6	2.50	0.75	Vertical	1.67
7030	2.75" rocket	7	0.92	0.23	North-South	3.00
7031	81mm mortar	7	1.42	0.27	East-West	1.58
7032	8" nail (corner)	0	0.67	0.02	Vertical	0
7033	8" nail (corner)	0	0.67	0.02	Vertical	0
7034	8" nail (corner)	0	0.67	0.02	Vertical	0
7035	8" nail (corner)	0	0.67	0.02	Vertical	0

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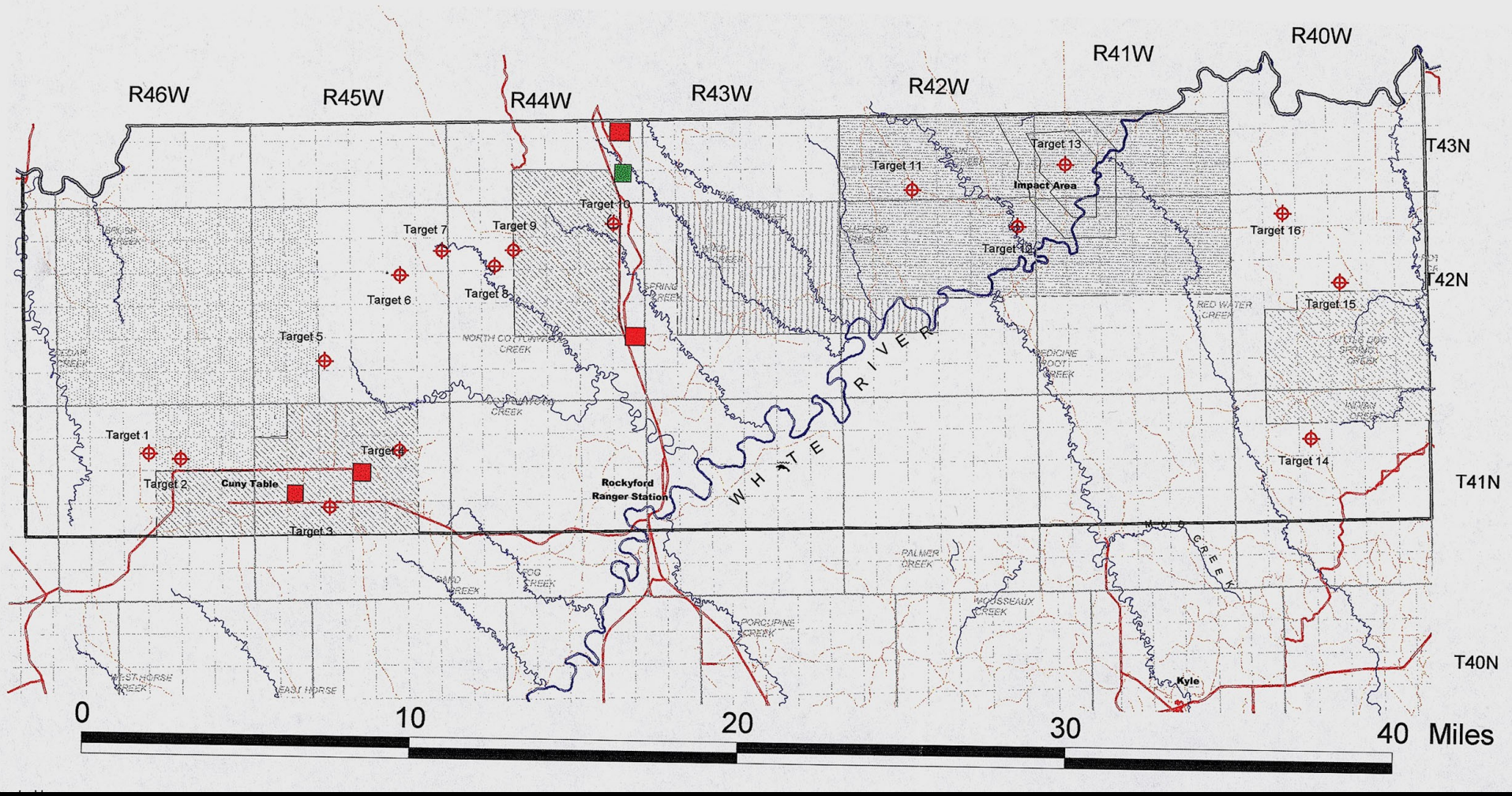
Demonstration Locations

- Four major targets/impact sites at Badlands Bombing Range comprising 1,232 acres
- Additional data acquisition of 1,018 acres included areas in Sections 1, 2, 4, 6, 7,
- Calibration Site on Cuny Table
- Cuny Table Bombing Target

Badlands Bombing Range
Site Map



Target II East of Scenic (Bouquet Table)
Historical Aerial Photo

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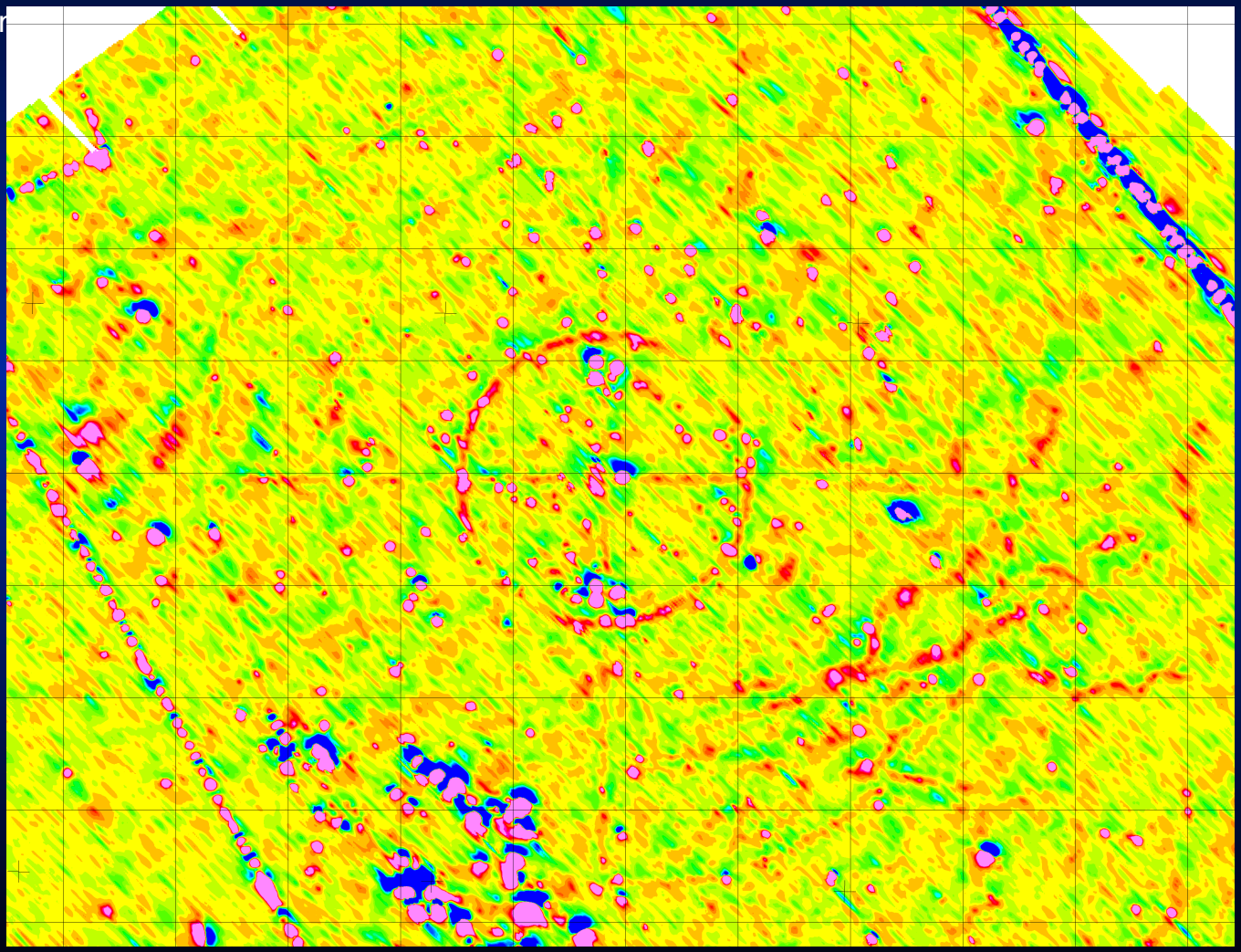
Anomaly Map, Bouquet Table



200 X 200 ft grid cells

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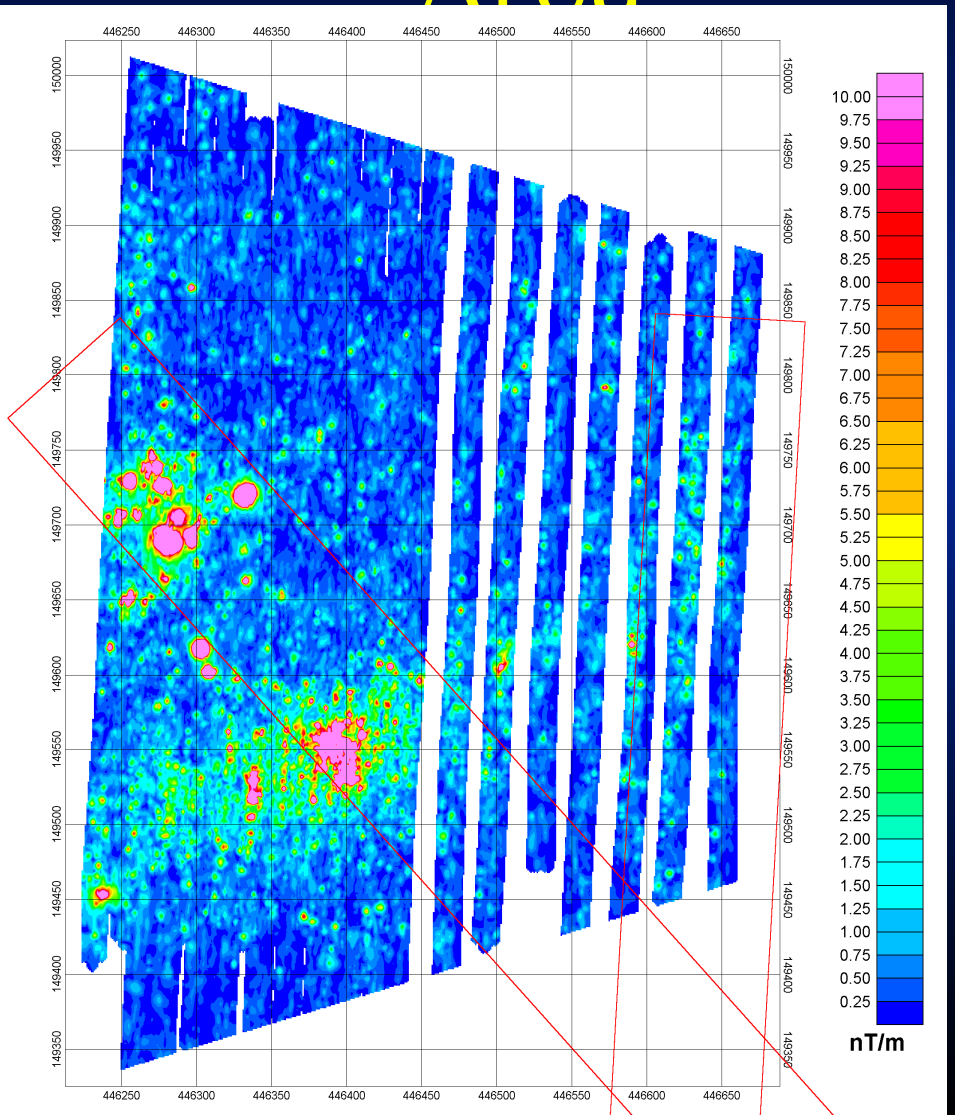
Analytic Signal, AF Retained Area



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2000 Test Results

- Reduced magnetometer spacing and higher sampling rate provides opportunities for more advanced processing and lower cost surveying. (Pass interleaving not required)
- Coverage at > 200 acres/day
- Improved positioning
- Larger, more complete test site

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Current Airborne Technology Capabilities

- Individual UXO targets in the “near-surface”
- Waste burial sites down to 20 feet or more
- Resolution: 5 – 7 lbs proven at a depth of 2 feet
- Positional Accuracy: better than 3 feet- Recent has been up to +/- 1’.

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Test Grid- SetupTips

- Always do one to validate performance
- Large area with good approach zone
- Items spread out to separate anomalies
- Bracket by adding small and deep items
- Include non ferrous
- Include geometric shapes
- Do ground based geophysical mapping with the same sensor before and after seeding

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Lessons Learned

- Always fly at multiple heights to predict performance for various terrain and vegetation standoffs. … 2,4,6,8,10 M? Determine what you can see at various heights and what is invisible?
- Add clutter areas for masking tests and areas with a specified magnitude of ferrous and non ferrous items per unit area.
- Purpose is for application as a standoff distance to determine contamination limits (impact area) or for pits and trenches.

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Predictions from standoff heights

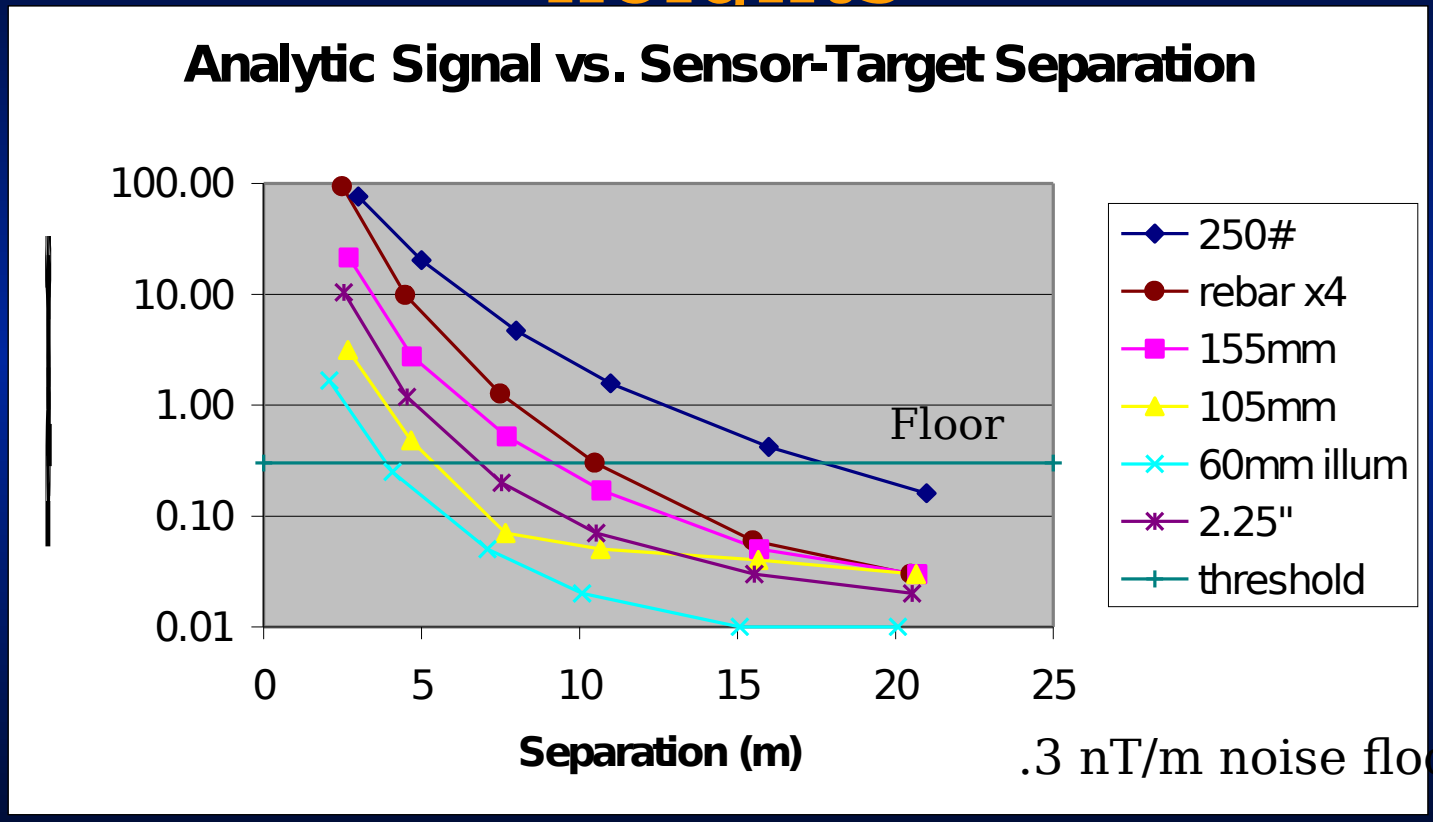

Figure 5. Plot of Analytic Signal vs. Sensor Height from selected single targets on the BBR test grid. Results are generated from the upward continued survey data and are consistent with the measured data at the Stronghold Table, although clusters of targets are visible at significantly higher altitudes than the single items shown here.

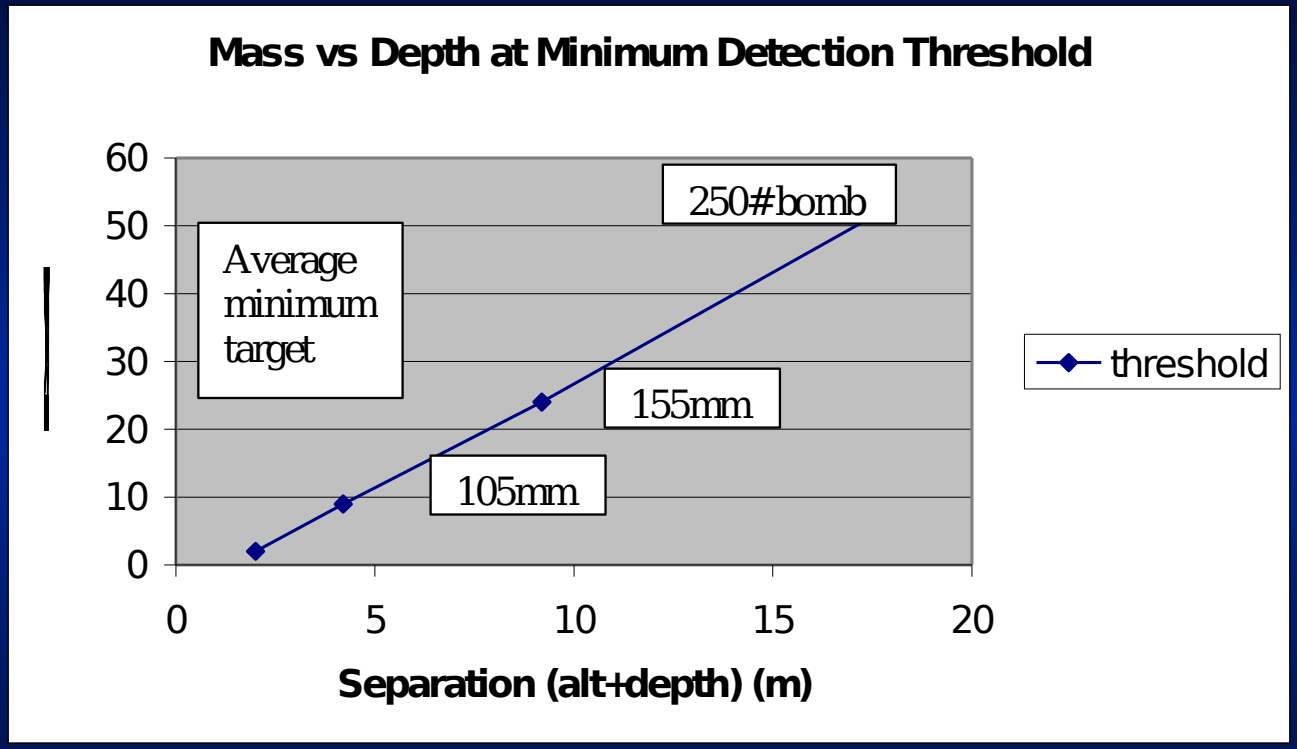

Figure 6. Mass vs Depth for selected UXO items at BBR test grid. The three ordnance items specified are derived from actual readings. The minimum point is a composite of the smaller targets in the grid. This illustrates the separation distance at which targets fall below the analytic signal threshold. Targets with a mass above the threshold line will be detectable at that depth.

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Pit Identification Predictions

Standoff Distance (sensor to item)	Ferrous Mass (equivalent point source)
5 M	10 Kg
10 M	25 Kg
15 M	42 Kg

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Summary

- Airborne magnetometry can find individual point sources or clusters of ferrous material
- The closer you are to the ground, the smaller the items- down to 5-7#. Large items are visible at tree top heights
- Surveys are performed as a stand off sensor with no ground contact
- Commercial and prototype systems are available now